OVERVIEW OF GEOCONTAINER PROJECTS IN THE UNITED STATES

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ABSTRACT

This paper discusses design and cost parameters for several geotextile geocontainer projects where geocontainers have been successfully filled with sandy materials and placed in water depths up to 70-ft using split hull bottom dump barges. Two very successful geocontainer projects in the U. S. were the Red Eye Crossing, U.S. Army Engineer District, New Orleans, and the Marina Del Rey project, U.S. Army Engineer District, Los Angeles. Two geocontainer projects in New York that were filled with fine grained maintenance dredged material were not as successful. It was determined from this study that the cost of geocontainer structures are about one half to two-thirds the cost of rock structures. It was also determined that with the proper equipment and geotextile fabrics, contaminated dredged material could be contained successfully and economically in geocontainers.

Keywords: Dredging, geotextile containment, dredged material, split hull bottom dump barge.

INTRODUCTION

A number of geocontainers have been successfully filled with sandy materials and placed in water depths up to 70 ft using split hull bottom dump barges in Europe, Malaysia, Taiwan, Japan, and the U. S. Two very successful geocontainer projects in the U. S. were the Red Eye Crossing, U.S. Army Engineer District, New Orleans, and the Marina Del Rey project, U.S. Army Engineer District, Los Angeles. The Red Eye Crossing project was located two miles south of Baton Rouge, LA, on the Mississippi River and the Marina Del Rey project was located in Los Angeles, CA.

Attempts to contain highly plastic, fine-grained, maintenance dredged material in geocontainers during two demonstration projects in New York Harbor for The Port Authority of New York and New Jersey experienced minor problems with seam failures. These failures were due to the containers being under designed, over filled, or not protected from sharp edges by fabric protection slip sheets when deployed in less than desirable bottom dump split hull barges. To overcome some of these problems and misconceptions with design, costs, filling and placement methods, an overview of U. S. projects is discussed in this paper. There have been several fabric seam improvements and improved geocontainer deployment methods developed as a result of these projects. Several projects are in the planning and design stages. One large sand filled container project is to be constructed during the summer of 1997.

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The Red Eye Crossing project consisted of construction of six underwater bendway weir dikes for a total length of 7,000 ft of channel training structures to reduce dredging costs. Three cubic yard Geobags were placed from a flat top barges with front end loaders whereas the geocontainers were placed with split hull bottom dump barges.

Details concerning quantities and cost for the Red Eye Crossing project are based on unit cost per volume of fill material. This project consisted of 38,000 three cubic yard woven polypropylene geobags that were mechanically filled with sand for a total unit cost of $28.00 per cubic yard (cy). The bags were 12 ft in circumference and 12 ft long, but when filled and sewn closed they were about 4 ft in diameter and 8 ft long.

The project also contained 556 geocontainers that were mechanically filled (clam shell) with sand. These geocontainers contained between 100 cy to 550 cy of sand for a total unit cost of $16.41/cy for the geocontainer and filling. The containers were 45 ft in circumference and varied in length from 40 to 115 ft. The bin width was 12 ft and the barge opening was 9 ft, therefore the percent opening was 75 percent. The maximum length to width ratio varied from 3.3 to 9.6. The woven polypropylene geocontainers had air vents constructed in the center top and at each end. There was no barge liner specified for this project.

To prevent failure the geocontainers were filled to about 60 to 70 percent of the theoretical fill volume. The theoretical volume is defined as the cylindrical volume of the container. Prior to placement of the geocontainer in the barge, the barge bottom vee was filled with about 150 cy of sand because the geocontainer dimensions supplied by the contractor were too short for the depth of the bin. Placement of sand in the barge vee raised the geocontainer to a better position to accommodate sewing of the top.
As the barge opened this layer of sand was eroded out of the vee by the 4-ft/sec river currents. The geocontainers fell down and out of the barge very uniformly without twisting or diving.

In the beginning of the project there was evidence that perhaps three of the 556 geocontainers had failed. Failure was suspected because floats installed inside the containers floated to the water surface after deployment. This problem was remedied when the dredged material fill volume was lowered to the 70 percent of the theoretical fill volume of the container as specified in the contract.

The other alternative construction method for the Red Eye Crossing project was to use rock fill at a cost of $16.00 to $20.00 per ton (0.67 cy/ton) or a cost of $24 to $30 per cy. The cost of the 3 cy sand bags was about the same as the cost of rock by volume but the cost of the geocontainers filled with sand was 50 percent more economical than rock fill by volume.

The geocontainers were not only more cost effective than rock but they did not pose any potential navigation hazards for large ships carrying oil to refineries in Baton Rouge, LA. The total project cost of $6,000,000 was theoretically recovered in less than two years after completion because of reduced maintenance dredging costs. The project is operating beyond expectations and three more sand filled geocontainer projects are planned further down stream in the near future. The New Orleans Corps of Engineers will not allow rock filled sedimentation training dikes on the Mississippi River south of the Baton Rouge, LA bridge.

After about five months into the project three of the geocontainers were instrumented with strain gages and pressure cells with funds provide by the U. S. Army Engineers, Waterways Experiment Station (WES), Vicksburg, MS, Construction Productivity Research Program (CPAR). The WES and TC Mirafi Corporation both contributed $400,000 each to this program. These costs were not included in the project cost. The geocontainers were dropped in water depths of 60 ft. The strain gage data indicated that the geocontainers had a factor of safety very close to 1.0. Since the completion of this project some of the geobags and containers located near the riverbank have lost a small amount of sand because of the very open geotextile fabric but this loss of sand has not caused any problems. This problem will be remedied in the future with tighter and stronger fabrics to prevent the loss of sand.

**MARINA DEL REY PROJECT, OCT - NOV 1994**

The Marina Del Rey project consisted of mechanically filling 44 geocontainers with an average volume of 1300 cy of contaminated dredged sand. The outer geocontainer consisted of a woven polyester geotextile with an ultimate tensile strength of 1000 pounds per linear inch width (pli) in both the warp and weft. The inner liner was a 16-oz non-woven polyester geotextile that served as a filter to prevent contaminated soil from escaping. The 7 to 8 percent fine-grained soil in the dredged sand was contaminated with lead, zinc, and copper.

The total project cost for mobilization and demobilization, cost of the geocontainers, cost of dredging and filling the geocontainers with 55,100 cy of dredged material was $4,374,098 or a unit cost $79 per cubic yard. These high cost were attributed to delays caused by a long hauling distance, difficulty in
deployment of the first geocontainer when it became lodged in the barge opening for a one week delay. Also cold, wet, weather conditions and delays caused delays by the contractor’s frequent changes in personnel and getting them up on the learning curve.

The cost for forty-three of the geotextile containers was $25,950 per container or a unit cost of $20 per cubic yard. The first container cost $21,620 or about $17 per cubic yard. The original plan was to fill the geocontainers with 2500 cy of dredged material for a unit cost of $10 per cubic yard for the geocontainer. When the very coarse and moist dredged sand would not flow freely out of the narrow opening in the split hull bottom dump barge the fill volume was reduced to 1300 cubic yards, therefore increasing the geocontainer unit cost to $20/cy.

The geocontainers were 200 ft long and 120 ft in circumference. The initial circumference was 90 ft but was increased to 120 ft after the first geocontainer became lodged in the barge narrow opening. The sand in the geocontainer was finally liquefied and the container was deployed. It was assumed that additional fabric slack in the bottom vee of the barge would facilitate deployment of the geocontainer. The geocontainers were only filled to about 15 to 22 percent of their theoretical fill volume. The bin length was 176 ft and the modified width was 22 ft. The length to width aspect ratio was 8.0. The barge opening width to bin width ratio was 50 percent.

The barge was lined with a woven polypropylene fabric but was removed after the first container became lodged. There was no geocontainer instrumentation at Marina Del Rey and there was no evidence of geocontainer failure.

**NEW YORK GEOCONTAINER, APRIL 1995**

The Port Authority of New York and New Jersey mechanically filled one geocontainer with about 3600 cubic yards of highly plastic fine grained maintenance dredged material with a clam shell dredge. There was very little evidence of debris. The outer container consisted of the same woven polyester fabric that was used at Marina Del Rey. The inner liner consisted of a 12 oz non-woven polypropylene fabric to prevent loss of fines. The density of the material in the geocontainer was about 1.23. The in situ density was about 1.3.

**Bulking Ratio.** To compute the saturated bulking ratio for the in situ volume to the volume placed in the barge, either of the following equations may be used when the saturated density, void ratio or moisture content are known:

\[
\text{Bulking Ratio} = \frac{V_o}{V_i} = \frac{Q_i - 1}{Q_o - 1} \quad \text{or} \quad \frac{e_o + 1}{e_i + 1} \cdot \frac{G_s + 1}{G_s + 1} \quad (1)
\]

Where:
- \(V_o\) = volume of dredged material after excavation and disposal in the barge
- \(V_i\) = volume of in situ channel sediments prior to dredging
- \(Q_o\) = density of dredged material in the barge
\( \varrho_i \) = in situ density of channel sediments prior to dredging

\( e_o \) = void ratio of dredged material in the barge

\( e_i \) = void ratio of in situ channel sediments prior to dredging

\( \varepsilon_o G_s \) = moisture content of dredged material in the barge times the specific gravity

\( \varepsilon_i G_s \) = in situ moisture content of channel sediments times the specific gravity

Where the in situ saturated density, \( \varrho_i \), and the density in the barge, \( \varrho_o \), are known, then the bulking factor for the dredged material in the barge is calculated as follows:

\[
\frac{V_o}{V_i} = \frac{1.30 - 1}{1.23 - 1} = 1.30 \text{ or } 130 \text{ percent bulking ratio}
\]

Therefore, the bulking ratio of the dredged material in the container and barge was about 130 percent.

Dredged materials dropped in geocontainers will not bulk an appreciable amount when dropped through the water column. But, if allowed to drop through the water column without containment the bulking ratios may increase by orders of magnitude greater than the bulking ratio calculated due to excavation and placement in the barge and geocontainer. It was estimated from laboratory model and field tests conducted during the Dredged Research Program at WES that bulking ratios of 200 to 1000 percent are not uncommon depending on the type dredged material, grain size, salinity, drop depths and current conditions. Sand capping of these highly plastic fine-grained materials is impossible at these very low densities, fluid mud consistencies and high void ratios. Dredged material contained in geocontainers may be capped without any difficulty or loss of material or they may not be capped at all and simply allowed to consolidate without capping.

The container was 206 ft long and 150 ft in circumference. The geocontainer was only filled to 30 percent of its theoretical volume. The bin was 168 ft long and 41 ft wide. The length to width aspect ratio was 4.1. The barge opening width to bin width ratio was 33 percent.

The barge was lined with a 40 mil thick high density polyethylene (HDPE) liner to prevent excessive frictional forces in the fabric. The HDPE that was lapped in the barge vee bottom was not long enough to protect the geocontainer from the closing bars during deployment.

The geocontainer was dropped in about 57 ft of water. There was evidence from one float coming to the surface and a dredged material plume near the water surface that the geocontainer had separated. The geocontainer was instrumented with both strain gages and pressure cells. The strain gages indicated that the geocontainer experienced higher strains than predicted during deployment and impact with the ocean floor. Diver inspections also confirmed that the geocontainer had separated along a major longitudinal bottom seam.

The primary causes of failure were attributed to too much dredged material in the geocontainer and not enough protection for the geotextile fabric during deployment. A stronger fabric may have more successful. The polyester fabric may have partially failed when the barge was closed onto the fabric
prior to filling. As the barge was towed to the mud dumpsite the fabric that was clamped between the barge halves could have been further damaged due to abrasion during transport. These barge halves are very flexible and the two halves could have abraded the fabric during the four-hour trip to the mud dumpsite.

Cost of the geocontainer was $10 per cubic yard and the cost of dredging was $5 per cubic yard. The cost for design and instrumentation installation was not included.

**TWO NEW YORK GEOCONTAINERS, JUNE 1996**

The Port Authority of New York and New Jersey mechanically filled a 4000 cy barge with maintenance dredged material that was then hydraulically dredged into a geocontainer located in a bottom dump split hull barge. Two geocontainers were filled with about 1700 cy of dredged material. The first container for the first drop consisted of only a woven polyester fabric like that used at Marina Del Rey and New York. The second geocontainer and second drop had a 12-oz non-woven polypropylene inner liner to control the loss of fines during deployment. The inner liner was installed to determine if an inner liner would be necessary to prevent the escape of fines. The split hull bottom dump barge was painted to provide a slick surface instead of using a HDPE liner for container protection. The containers were pre-assembled with three hydraulic filling ports that were tied and sewn closed in the field. Only the center filling port was used during this demonstration.

The first container was 120 ft in circumference and 195 ft long. The geocontainer was only filled to about 21 percent of its theoretical volume. The bin was 168 ft long and 35 ft wide and the length to width aspect ratio was 4.8. The barge opening width to bin width ratio was 33 percent.

The second container was 105 ft in circumference and 195 ft long and it was filled to 27 percent of its theoretical volume.

The wet bulk density for both drops was about 1.17 gm/cc in the barge and geocontainer. The in situ density of the dredged material in the channel was 1.3 gm/cc. The bulking factor from the in situ volume to the volume in the barge and geocontainer was calculated to be 176 percent.

During cleaning and painting of the barge in dry dock the contractor simply could not afford to spend the amount of time and money necessary to properly prepare the barge. Old pieces of concrete stuck to the barge closing bars and jagged metal parts had to be chipped and ground down the best that they could in the time allowed. It was observed that the barge had been damaged when it was used as a rock barge. Where split hull barges have been used to haul rock, they become deformed in the bottom vee area and cannot be properly closed. During normal dredging activities these damaged barges are often sealed with sandbags placed in the bottom vee to prevent the loss of fine-grained loose or fluid dredged materials.

When these barges are maintained properly and are not misused they have a large rubber seal and steel plate welded in the bottom vee to prevent the loss of dredged material. When this seal is damaged or
has been removed, such as in the case with the barge used for this project, this size opening will allow
dredged material to escape. But, when these barges are used to haul rock and after the two, barge
halves have been damaged due to excessive loading with rock, this opening could be much wider. This
barge was not inspected in the closed position, which is a very important observation that should be
made prior to geocontainer placement.

During transport of the first geocontainer to the dumpsite a tremendous amount of water was observed
entering and exiting between the barge halves at either end of the bin around the end of the
geocontainer. There was less water and pumping action during transport of the second geocontainer.
This pumping action during transport could have possibly caused the fabric to enter the opening
between the barge halves causing abrasion and fabric damage.

The first geocontainer fell uniformly from one end of the barge to the other without twisting or turning.
Inspection after placement and review of the instrumentation data indicated that the first geocontainers
might have failed prior to or during release from the barge. During deployment the strain gage data
indicated very little strain which meant that the geocontainer had possibly failed prior to or during
opening of the barge. Diver inspection revealed a 40-ft long failure adjacent to a seam.

The second geocontainer twisted near the bow during deployment and went down at an angle of about
25 degrees from the horizontal. Inspection of the second geocontainer after placement and review of
the instrumentation data indicated that the container exited the barge satisfactorily but the geocontainer
seemed to have sustained damage on impact with the bottom. The outer woven polyester liner was
damaged in four locations that varied in length of only a few feet. The largest opening and loss of
material occurred at the bow end at the left corner. The container maintained a definite shape and
curvature on the bottom indicating very little loss of material during deployment and impact. The divers
found that most of these failures occurred in seams but one occurred in a panel. Both the inner and
outer liners appeared to have failed in the bow end of the container.

The strain gage data indicated strains approaching fabric failure during impact with the sea floor. The
factor of safety was considered to be only slightly less than 1.0.

The second container may have survived impact if it had not sustained partial damage during
deployment. Unprotected sharp edges from the close bars and concrete may have contributed to
weakening the geocontainer prior to impact.
SUMMARY

Table 1 is a summary of the container volumes, theoretical volume versus fill volume ratios, bin length versus width ratios, bin width to opening width ratios, container unit cost, total unit cost for the container and dredged material fill and rock fill volume cost.

Table 1. Summary of Geocontainer Information

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Volume cy</th>
<th>Theoretical Vol/Fill Vol &amp; Opening Width/Bin Width</th>
<th>Aspect Ratio Container Length to Width</th>
<th>Fabric Cost/cy of Containment</th>
<th>Total Cost for Geocontainer and Dredge Sand Fill per cubic yard</th>
<th>Total Cost for Rip Rap Rock Fill per cubic yard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Eye Crossing Geobags</td>
<td>3.0</td>
<td>80% to 75%</td>
<td>NA</td>
<td>$9.00</td>
<td>$28.00</td>
<td>$24 to $30</td>
</tr>
<tr>
<td>Red Eye Crossing Geocontainers</td>
<td>550</td>
<td>60 to 70% to 75%</td>
<td>3.3 to 9.6</td>
<td>$5.00</td>
<td>$16.41</td>
<td>$24 to $30</td>
</tr>
<tr>
<td>Marina Del Rey</td>
<td>1300</td>
<td>15 to 22% to 50%</td>
<td>8.0</td>
<td>$16.63 to $19.96</td>
<td>$79.38</td>
<td>Disposal Contaminated Sand</td>
</tr>
<tr>
<td>New York April 1995</td>
<td>4000</td>
<td>30% to 33%</td>
<td>4.1</td>
<td>$10.00</td>
<td>$15.00</td>
<td>Disposal of Maintenance Dredged Mat.</td>
</tr>
<tr>
<td>New York Cont. #1 June 1996</td>
<td>1700</td>
<td>21% to 33%</td>
<td>4.8</td>
<td>$10.00</td>
<td>$15.00</td>
<td>Disposal of Maintenance Dredged Mat.</td>
</tr>
<tr>
<td>New York Cont. # 2 June 1996</td>
<td>1700</td>
<td>27% to 33%</td>
<td>4.8</td>
<td>$10.00</td>
<td>$15.00</td>
<td>Disposal of Maintenance Dredged Mat.</td>
</tr>
</tbody>
</table>

CONCLUSIONS

It was concluded that when geocontainers are not overfilled beyond a certain ratio which has not been determined for fluid mud dredged materials or designed beyond their seam strength limits then they can be placed successfully. It was also concluded that when proper placement equipment and fabric protection measures are utilized, the geocontainers can be successfully deployed from split hull bottom barges without damage. It was concluded that this new and innovative containment technique is technically and economically feasible and geocontainers can be properly designed for containment of dredged material, especially contaminated sediments. Depending on the nature of the project cost for the geocontainers and dredged material the cost varied from a low $16 per cubic yard at Red Eye Crossing to a high of $79 per cubic yard at Marina Del Rey. The cost for the geocontainers at New
York were about $10 per cubic for the container and $5 for dredging for a total cost of $15 per cubic yard, but there was considerably more cost involved because this was a demonstration project.

One very important observation was the bulking factors for a geocontainer filled with highly plastic fine-grained dredged material. The bulking factors at New York ranged from 130 percent for mechanical fill and 183 percent for combined mechanical and hydraulic fill. Placement of these types of dredged materials through the water column could be orders of magnitude higher than these values (1300 to 1830 percent).

**RECOMMENDATIONS**

The following recommendations should be considered during design and implementation of future geocontainer projects:

1. It is recommended that the barge opening be constructed as wide as possible. The minimum opening widths should be established for different types of fill materials and geotextile fabrics. The opening width to bin width for Red Eye Crossing was 75 percent, for Marina Del Rey was 50 percent, and for New York was 33 percent. It is recommended that the fill height ratio to bin width opening be less than 1.3.

2. The rate of opening should be investigated as to its effect on geocontainer loading. The current opening rate for most all bottom dump barges encountered is about one minute.

3. Long barge bins should be partitioned to reduce the length to width aspect ratio in an attempt to prevent long geocontainers from twisting during deployment. The ratio for Red Eye Crossing varied from 3.3 to 9.6, Marina Del Rey was about 8.0, and New York varied from 4.1 to 4.8. It is recommended that an aspect ratio of 2.0 or less be used for geocontainers.

4. The geocontainers need to be filled to an optimal fill volume similar to what was achieved at the Red Eye Crossing project, which was about 60 to 70 percent. The ratios used for the Marina Del Rey and New York geocontainers were entirely too low to be economically feasible. To make this concept economically attractive this ratio needs to be greater than 50 percent. It must be noted that the Marina Del Rey and New York projects were considered to be research demonstration projects and never reached full production like the Red Eye Crossing Project.

5. It is recommended that very stiff fabrics such as woven polyproplyenes be used to construct geocontainers that are filled with very fine grained maintenance dredged materials and sandy materials. When fluid dredged material mud is contained in very hydrophilic and flimsy polyester fabrics, they have a tendency to find and fill into every nook and cranny in the barge when under pressure. Polyester yarns are much more subject to abrasion damage than polypropylene yarns. The polypropylene fabrics are less subject to yarn abrasion and are more robust and have a higher survivability to construction damage. The use of polypropylene yarns has been shown to reduce the amount abrasion damage during placement, filling, and transport.
6. It is also recommended that the influence of different types of dredged materials be evaluated as to their influence on geocontainer survivability during impact. The use of a clamshell versus a hydraulic pump may also need to be evaluated for each location.

7. When using split hull bottom dump barges the geocontainer must be protected from the closing bars and all sharp and rough edges that might damage the geocontainer fabric. It is recommended that a very durable and robust geosynthetic liner or sleeve be constructed to protect the geocontainer as it passes through the barge opening.

8. Recommend that higher seam strengths be investigated to lower geocontainer cost and to reduce seam failures. New seaming techniques have shown that seam strengths of near 100 percent of the fabric strength can be achieved. Past experience has only been 50 to 60 percent.

9. Recommend that fabric friction tests be conducted for woven polypropylene fabrics on steel, HDPE and other proposed geotextile liners.

10. Do not recommend indiscriminate barge modification without an analysis of its geometry and probability of successful deployment of geocontainers. Bin width modifications are generally not recommended for successful deployment. Existing equipment can be used to deploy geocontainers and it is not necessary to design specialized equipment for split hull or pocket barge placement.

11. Recommend that GPS systems be used to locate the geocontainers after placement to evaluate any drift or skating effects due to currents or shape effects during free fall through the water column. Accurate placement of geocontainers during construction of sub-aqueous structures such as Red Eye Crossing or for deep-water disposal of contaminated materials is very important.

ACKNOWLEDGMENTS

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